MULTILATERAL TECHNOLOGY—1

Multilateral technologies increase operational efficiencies in Middle East

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The willingness by Middle East operators to develop multilateral drilling technologies, despite inherent risks and costs, has resulted in increased production rates, advanced well configurations, and an improved understanding of operational techniques.

Middle East drillers are now able to competently drill and complete multiple, separate, accessible, and pressure-isolated laterals from a single parent well bore. In 1996, it was estimated that more than 35 multilaterals of various descriptions were drilled in the Middle East.

Changing oil field development economics have challenged operators and service companies to produce greater quantities of oil at reduced costs. Deeper and more-corrosive environments are being produced to increase production capacities; and new technologies are being encouraged in the attempt to generate as much value from a well as possible.

This pursuit and the resulting development of new techniques have been major factors in reviewing former projects that were economically unfeasible, but has also extended the lives of existing fields in which production has been declining.

The concept of multilateral well completions is not new, and patented designs appeared as early as 1919. Other multilateral wells

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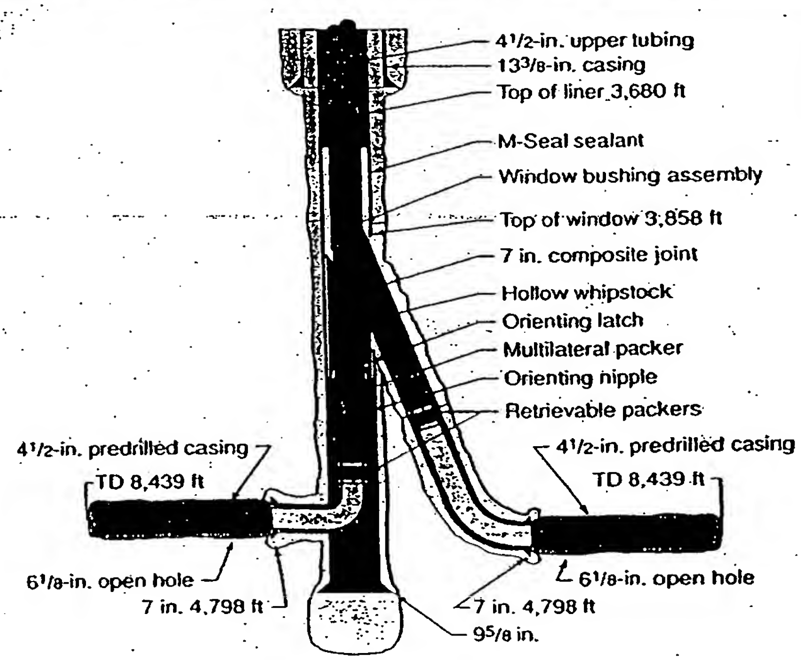
Fig. 1

FIRST MULTILATERAL WELL IN MIDDLE EAST



were documented during the 1950s in California and Russia. It has only been since the early 1990s, however, that the conceptual techniques have progressed sufficiently for the technology to be considered fully developed.

The values of the multilateral concept have long been recognized, but traditionally, completion techniques including remedial work have lagged in terms of implementation. However, most of these technical limitations have now been overcome.

To date, about 50% of the multilaterals in the Middle East have been open hole sidetracks with no liners or completion equipment.

Concerning the financial drivers for a multilateral well, the nonproductive or vertical part of the well is considered to be cost driven, whereas the productive part of the well, consisting of the deviated or horizontal sections, is considered to be value driven.

Thus, the technology and processes behind multilateral configurations must be carefully evaluated, ensuring that a particular multilateral configuration is the correct option for the scenario under evaluation.

As with all new and developing technologies, it must also be recognized that there may be technical and economic risks that should be carefully evaluated.

Multilateral technology can be used in a variety of scenarios including:

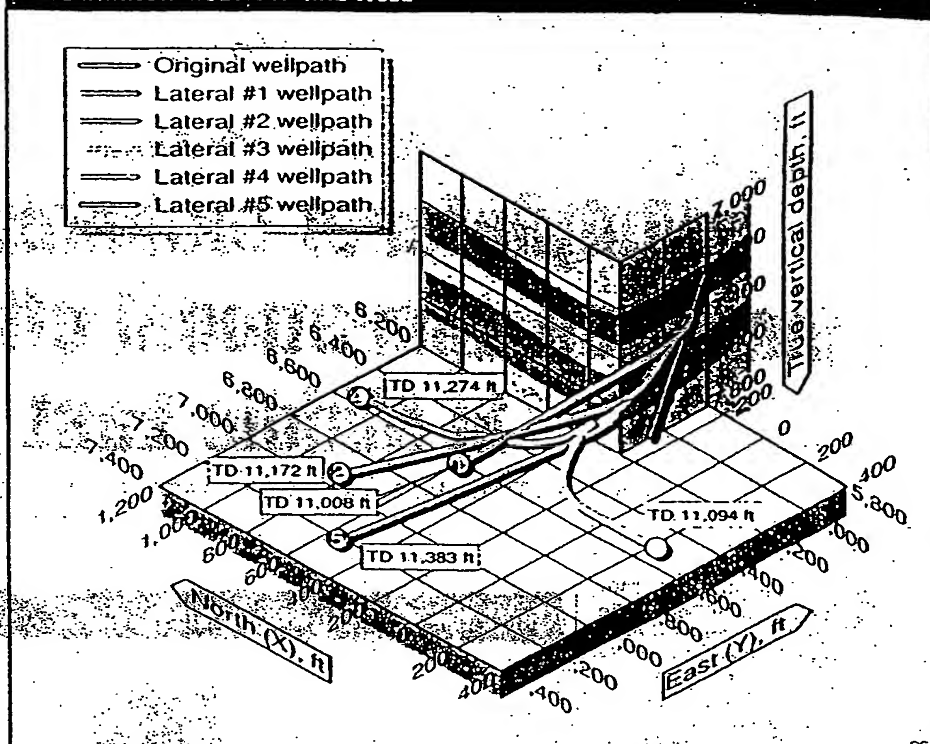
- The development of in fill field programs with limited slots.
- The extension of field life by accessing new reserves.
- The development of deepwater plays.

Generally, multilaterals can be divided into two categories:

1. Re-entry—Where an existing well is re-entered and multiple branches are drilled off of the existing

Fig. 2

FIVE-BRANCH MULTILATERAL WELL



well bore.

2. New development—Where a new well is designed and drilled, utilizing multiple branches and various completion types as required.

Design concepts

In a multilateral completion, a unique system may mechanically connect directional and horizontal laterals to a parent well bore, allowing production from the individual laterals to be selectively produced or commingled.

It is important that a multidisciplinary developmental team be employed for the initial planning stages. From the operator's side, the team should include drilling engineers, reservoir engineers, geologists, and petrophysicists.

From the service company's side, the team should include multilateral, completion, directional, and logging-while-drilling (LWD) specialists. Each member plays a significant role in the planning, design, and successful execution of the candidate well.

A workshop session has been an effective method for initiating the complex, well-planning efforts and establishing project objectives. The following guidelines represent basic objectives that must be considered:

1. Establish timeline
2. Evaluate all well criteria
3. Evaluate all completion design options
4. Identify problem areas
5. Create procedural outlines
6. Establish team rapport.

A second operational workshop session should be scheduled to familiarize personnel with various operational procedures, solicit field input for enhanced procedural efficiencies, and coordinate operational roles.

Successful planning of a multilateral well can take up to 6 months.

Multilateral drilling

Drilling operations can be broken down into two stages beginning with kicking-off the lateral branch and followed by drilling the horizontal section.

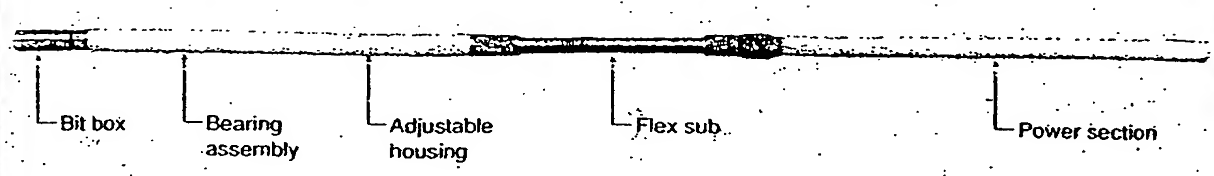
The method used to initiate lateral legs from the parent well bore depend on:

- Whether the parent well is cased or open hole.
- Whether the well is a preplanned multilateral or a re-entry.
- The final design of the multilateral completion.

In certain cases, if the multilateral aspect of the well has been planned from the start, special casing joints, prespaced and preorientated against the target formations, may already

Fig. 3

FLEX MOTOR USED FOR KICK-OFF



be installed in the well to allow easy lateral drilling capabilities with a whipstock.

If the well is a preplanned multilateral, considerations should include the careful spacing of casing against the target formations. This ensures that the casing collars or centralizers do not impede window cutting.

Also, the degree of dogleg severity through which the whipstock is set should be carefully considered, especially since it can be difficult to retrieve if the dogleg severity is too high.

However, it is often not possible to preplan these factors, and the multilateral team should gather as much information as possible concerning the sidetracked section, especially in the case of re-entries.

This information should include casing condition, cement integrity, and formation properties. If the section is cased, there is the choice of:

- Milling a section, setting a cement plug, and using a motor to orientate and drill off the plug in the desired direction.
- Setting an orientated retrievable whipstock, cutting a window, and using this to initiate the kick-off.
- Pulling the casing string and kicking off in an open hole with a whipstock or cement plug.

In certain re-entry cases, the operator may wish to avoid drilling. For example, in situations where drilling 6-in., slim-hole laterals may limit production or create problems with tool entry and completion procedures, or if complex casing configurations impose operational difficulties.

For instance, take a situation where a 7-in. liner had been run in an 8½-in. hole section below 9⅝-in. casing. In order to drill out 8½-in. lateral sections, the operator may be faced with either sidetracking out of the 9⅝-in. casing, or pulling the 7-in. liner. Both of which may be impractical.

Another alternative would be to mill out the liner overlap plus an additional 100 ft of 7-in. liner below the shoe. An 8½-in. lateral can then be drilled off a cement plug within the open hole section that was created. This is a commonly used technique in the Middle East.

Whipstocks vs. milling

Although milling techniques have improved in recent years, most operators in the Middle East prefer whipstock sidetracking over section milling. This is because hole sections can be sidetracked quickly, on the order of 2 days, using a retrievable whipstock system.

Whipstock methods may be more costly than section milling, but they eliminate the potential problems of trying to kick-off cement plugs.

Integrated whipstock and milling assemblies that reduce tripping are now becoming available. With these assemblies, it is possible to orientate, set the whipstock, and open the casing window, all in a single trip.

If the parent well bore is an open hole, the lateral leg can be initiated by:

- Setting a cement plug and kicking off the plug
- Drilling an open hole sidetrack by time drilling.
- Setting an open hole whipstock.

Although low-side open hole sidetracks are most common, it is possible to drill high-side open hole sidetracks by setting an open hole packer, then orientating a whipstock on it.

When sidetracking with the open hole method, it may be possible to drill more than one branch without tripping out. If it is fairly easy to sidetrack without an aggressive motor bend, it may be possible to kick-off and drill the lateral section with one assembly, and then pull back and drill further sidetracks in a similar fashion. This saves valuable rig time by avoiding tripping out to reconfigure the bottom hole assembly (BHA).

If an open hole section is sidetracked without the use of a cement plug or whipstock, it may be difficult to re-enter the well bore in order to pull the BHA before the horizontal section is finished.

One factor that may determine how the lateral section is initiated concerns the completion type. If the completions are open hole, any method can be used. However, if any form of a tied-back completion string is run in the various lateral legs, then some sort of whipstock system, usually an integral part of the completion system, will be required.

Short-radius techniques

Another area of multilateral drilling technology that has gained increased attention is the application of intermediate and short-radius drilling techniques.

These techniques are of particular use in re-entry drilling where there are, for example, swelling clays that cause problems while drilling, especially if the zone has already been cased off in the original well.

In this case, it is better to avoid drilling the section again, and all re-entry drilling should be done in the lower, less-troublesome formations. Thus, there may be constraints on the vertical depth of the build section currently unachievable with conventional drilling motor and surveying technologies.

It is now possible to drill with doglegs as high as 70°/100 ft using special flexible mud motors and MWD systems run in compressive service-type flex collars. For dogleg severi-

ties in excess of 70°/100 ft, it is necessary to use articulated systems.

These systems are capable of drilling anywhere from 60°/100 ft to 2°/ft. With increasing dogleg severity, however, the drilling operation becomes more difficult, and must be balanced against the potential benefits for this type of operation.

Potential constraints on drilling short and ultrashort radius laterals depend on the lengths and types of logging tools, LWD or wire line, and also on the type of completion.

Lateral drilling

Increasing production rates is the primary objective for drilling and completing multilateral wells. Production rates depend on the amount and degree of reservoir exposed along the productive pay zone.

Increasing production rates can be achieved by either drilling the longest possible section in the pay zone, increasing the number of branches, or ensuring that the borehole is maintained in the pay zone for as long as possible.

Combinations of all three can also be considered. Multilateral wells with individual branches as long as 9,000 ft have been drilled in the Middle East. The branches do not necessarily have to be horizontal, and certain reservoir types, such as laminated formations, may require inclined well paths.

To facilitate the drilling of long, extended-reach branches, various techniques have been used. Avoiding excessive torque and drag and controlling drilling fluid properties is critical during the well-planning phase.

Downhole adjustable stabilizers are becoming increasingly common in these cases. These self-adjusting stabilizers control inclination even while the drilling assembly is continually rotated, overcoming problems of static friction normally encountered while sliding.

Table 1

LWD TOOL SPECIFICATIONS

Tool type	Tool OD, in.	Maximum rotating BUR*, °/100 ft	Maximum sliding BUR*, °/100 ft
Directional	3¾	50	116
Gamma	3¾	As per NMDC†	100
Resistivity	4¾	17	34
Neutron/density	6¾	6	16
Sonic	4¾	17.3	32

* BUR - Build up rate
† NMDC - Non-magnetic drill collar

This is a common problem for conventionally orientated motor drilling. Horizontal sections in excess of 15,000 ft have been drilled in the Middle East using downhole adjustable stabilizers.

Multilaterals in the Gulf area are now commonly drilled with two to six branches. While drilling multiple legs, considerable reservoir damage may occur if the laterals are exposed for long periods of time.

To reduce damage, specially formulated drill-in fluids can be used to optimize mud properties for high-angle horizontal drilling, limiting formation damage during long periods of exposure.

Logging multilateral wells

Running wire line logs through near-horizontal hole sections can be hindered because there is no slope for the tools to drop down. In addition, there may be difficulties in accessing the various lateral junctions.

However, LWD dogleg capabilities and tool variety have expanded (Table 1). Full quad-stack sensors consisting of resistivity, porosity, density, and sonic devices are now available for 8½-in. hole sizes allowing complete replacement of wire line equivalents.

For logging 6-in. holes, gamma and resistivity tools are widely available. Formation porosity can now be derived in 6-in. holes using nuclear density/porosity tools or sonic/caliper devices.

As well as replacing wire line logs used in formation evaluation, LWD logs provide sensor data for accurate landing and steering of the well bore, and provide the ability to stay within the pay zone as long as possible. These pay zone-steering techniques have been successful in maximizing reservoir exposure in a number of Middle East plays.

Typically, a resistivity device is used in combination with an earth model, derived from offset wire line logs. Predicted LWD log responses are computed under a number of different scenarios. These can then be compared to actual LWD log responses, and adjustments are made to the well bore path ensuring the well does not leave the pay zone.

Case History No. 1

This first multilateral well in the Middle East was drilled in March 1996. The completion consisted of two horizontal laterals encompassing about 3,500 ft of exposed hole in each leg (Fig. 1).

The operator drilled the lower lateral section as an extension of the parent well bore. The upper lateral section exited out a 9⅝ in., 40 lb/ft parent casing string into an 8½-in. hole. A 7-in. liner was set through the build until horizontal.

This liner was set with a composite joint across the hollow whipstock face as discussed earlier. The liner was cemented, and the lateral was completed then flow tested for 2 weeks.

The lower parent well bore was then reopened, and the junction was pressure tested. Because of the vertically permeable nature of the formation in which the exit was placed, cement squeezes were needed at the junction to pass the positive and negative pressure tests.

Plugs were then pulled from the parent and lateral well bores using full gauge and through-tubing diverters and a window bushing assembly. The window bushing assembly was ultimately left in the junction, and a 4½-in. tubing string was run in the upper completion.

This installation took longer to run than anticipated, nevertheless, both well bores became productive. The orientation nipple and mating lock device worked well. Based on this experience, modifications were made to the deflectors, enhancing efficiencies and best practice procedures.

Pentalateral

A graphic depiction of a multilateral well recently drilled in the Middle East is shown in Fig. 2. This five-branch well was drilled from an old, existing well under conditions of declining production.

The operator felt that drilling horizontal wells into the lower producing zones would increase production rates. Five zones were selected, and a well was designed to access them using intermediate-radius drilling techniques.

A 7-in. liner was set in an 8½-in. hole. Hole deviation at the 7-in. shoe was 45°. The target zones consisted of limestone layers separated from each other by hard dolomites.

The reservoir limestones were relatively soft, presenting little or no drilling problems. All legs were drilled with a 10 ppg, water-based atapulgite mud.

Lateral 1

The first target was positioned above the 7-in. liner shoe, requiring a sidetrack out of the liner. A retrievable whipstock was orientated with a measurement-while-drilling (MWD) system.

A 9-ft window was cut and cleaned out. Then a standard 4¾-in. motor with a 3° bend was picked up and run in with a tungsten carbide insert bit. Above the motor was positioned a directional/gamma MWD system located in a special flex collar.

From 9,773 ft, a curve was initiated at 45°, building to 81.1° at a rate of 29°/100 ft. Once the curve was complete, the assembly was pulled, and the motor reset to 1.15°. The lateral section was then drilled with a slow build rate until reaching an inclination of 89.30° at a total depth of 11,008 ft.

The hole was then circulated clean and displaced to brine. The whipstock was then successfully retrieved.

Lateral 2

Subsequent laterals were configured as 6-in. extensions of the original 8½-in. hole. In these cases, the 7-in. casing shoe was drilled out before the whipstock before the first lateral was set. A standard motor was used to drill out new formation, building angle from 54° to 61°. The assembly was then pulled, and a special flex-motor was picked up for the kick-off (Fig. 3).

The build rate for the curve was 55°/100 ft until the well was landed. Then the second lateral section was drilled. Drilling attributes of the flex-motor made for a predictable well path, allowing controllable build characteristics.

Minor adjustments to the inclination and azimuth were made as the lateral section was drilled. Once a total depth of 11,172 ft was reached, the hole was circulated with brine.

Lateral 3

After pulling back to the shoe, the same assembly and bit used to drill the second lateral section was used to sidetrack the existing 6-in. hole. The hole was then built to horizontal with a build rate of 24°/100 ft.

In addition, the hole was turned 90° to try and optimize production before reaching total depth of 11,094 ft. This section was also displaced with brine.

Lateral 4

As with the second and third laterals, the same assembly and bit was used in the fourth lateral. Another open hole sidetrack was drilled, and hole angle was dropped from 62° to 54°.

The same bit and motor used to drill the horizontal section of the second lateral and the entire third lateral, was also used in the sidetrack portion of the fourth lateral without any component changes.

The motor bend was then adjusted to 3.00° for the kick-off, but attempts to kick-off were unsuccessful due to a motor failure. A second motor was picked-up, and the kick-off and build to 91° was successful.

After pulling out to change the motor bend, the hole was then turned 60° to the right before reaching a total depth of 11,274 ft. Again, the hole was displaced to brine.

Lateral 5

With the same assembly used to drill the lateral section of the fourth lateral, the 6-in. hole section was open hole sidetracked. The motor was pulled, and the adjustable housing reset. Hole angle was then built from 62° to horizontal with a maximum dogleg severity of 58°/100 ft.

The motor was pulled out and the adjustable housing reset for the lateral section. A total depth of 11,333 ft was reached while maintaining the same azimuth throughout the section.

Summary of pentalateral

In this example, the multilateral was successfully drilled in 19 days, exposing over 5,000 ft of new pay in five separate zones. Whipstocks, open hole sidetracking, and intermediate to short-radius technology were successfully used to complete this operation.

The lateral branches were not completed in any form, and production was seen to increase dramatically from that of previous wells. The increase in production paid back all costs associated with the drilling of the multilateral within a matter of weeks. As a result, the operator has subsequently drilled a number of similar wells.

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